WISCONSIN FOREST MANAGEMENT GUIDELINES

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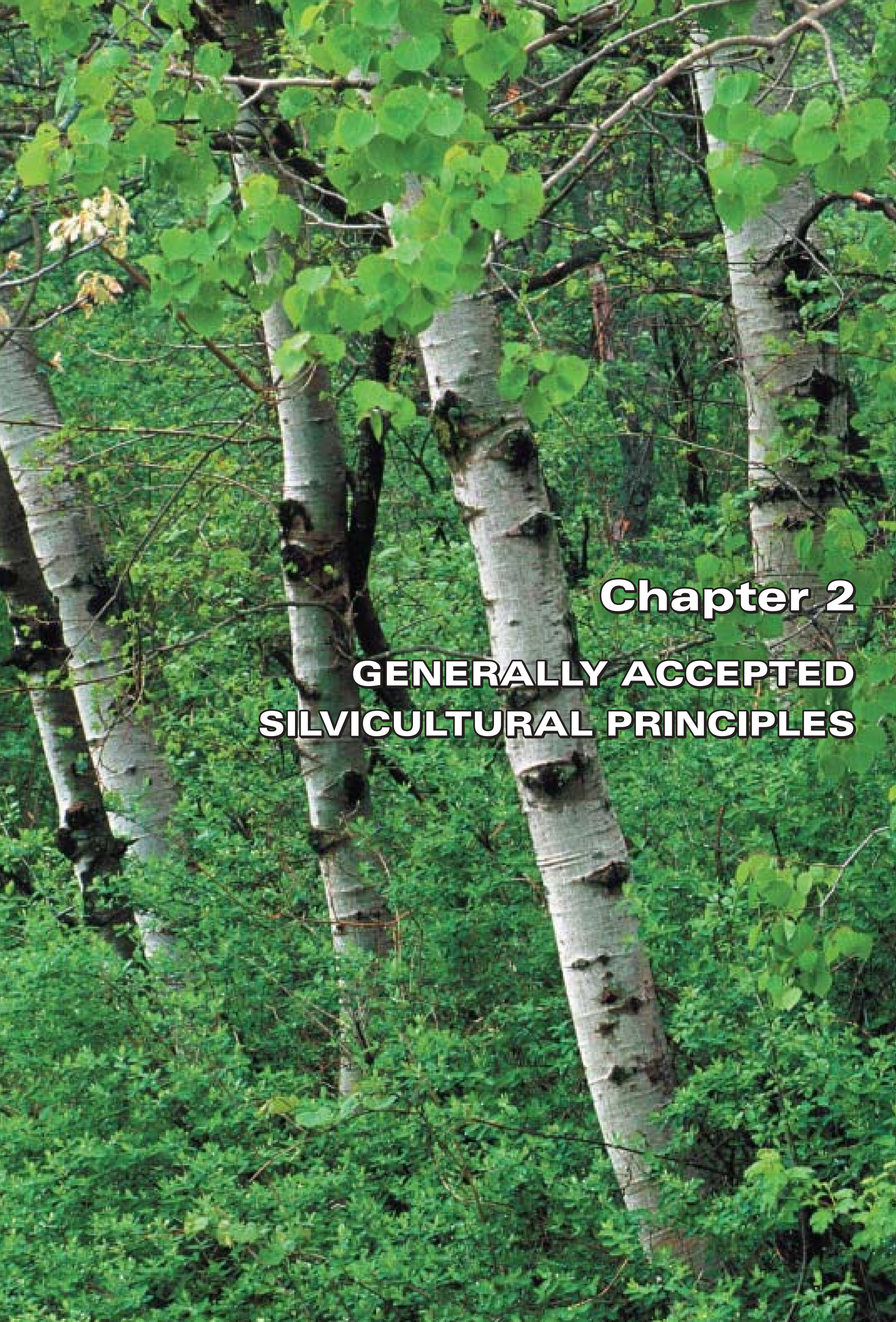

Chapter 2

GENERALLY ACCEPTED SILVICULTURAL PRINCIPLES

CHAPTER 2 — GENERALLY ACCEPTED SILVICULTURAL PRINCIPLES

The purpose of this chapter is to focus on growing stands of trees and the generally accepted silvicultural practices used in Wisconsin.

This chapter will:

- Provide an overview on the interdependence of compatible landowner objectives, a careful evaluation of site capability, and the selection of an appropriate silvicultural system – the three essential elements of sustainable forestry practices.
- Expand upon each of the preceding three essential elements of sustainable forestry practices.
- Identify, define and explain various silvicultural systems and their application to the common forest cover types in Wisconsin.
- Address other types of harvesting, unsustainable cutting methods, and passive management strategies.
- Provide examples of how to distill all the sustainable forestry considerations into an effective management prescription at the stand level.

For more detailed silvicultural information related to a specific forest cover type or forest management treatment, readers are referred to the Wisconsin DNR *Silviculture and Forest Aesthetics Handbook, 2431.5*.

Figure 2-1: Integrated guidelines recognize the forest as a community of related resources, rather than a collection of separate resources, as shown in this photo of the Baraboo Bluffs and Devil's Lake in Sauk County.

SUSTAINABLE FORESTRY

FOREST ECOLOGY

The science concerned with 1) the forest as a biological community dominated by trees and other woody vegetation; 2) the interrelationships between various trees and other organisms constituting the community; and 3) the interrelationships between organisms and the physical environment in which they exist.

SUSTAINABLE FORESTRY

The practice of managing dynamic forest ecosystems to provide ecological, economic, social, and cultural benefits for present and future generations (from Ch.28.04(1)e, Wisconsin Statutes).

SILVICS

The study of the life history, characteristics and ecology of forest trees. It involves understanding how trees grow, reproduce and respond to environmental variations. The silvics of a particular tree species would describe the climatic range, temperature and light requirements, moisture needs, thermoperiodicity, soil conditions and topography, life history and development, commonly associated trees and shrubs, and any environmental, insect and/or disease factors that affect its growth and survival.

SILVICULTURE

The practice of controlling forest composition, structure and growth to maintain and enhance the forest's utility for any purpose.

Sustainable forestry practices must be based on compatible landowner objectives, the capabilities of each particular site and sound silviculture. Each of these factors is equally important.

Landowners' goals and objectives might encompass a wide range of values and benefits such as commercial products, recreation, aesthetics, wildlife habitat, endangered and threatened resources, and clean water. Understanding landowners' goals and objectives is essential to ensure that prescribed forestry practices are relevant and will endure over time. Landowners' goals and objectives must also be compatible with sustainable forestry defined as the management of dynamic forest ecosystems to provide ecological, economic, social, and cultural benefits for present and future generations. The silvicultural principles discussed in this guide assume that landowners are committed to sustainable forestry.

Site capabilities help define sustainable forestry practices. Each particular growing space has its own set of environmental conditions affecting tree growth. Factors like soil type, aspect and climate influence the moisture and nutrients available to individual trees and must be considered to ensure long-term forest health and vigor (see "Site Evaluation and Stand Delineation," page 17).

Silviculture is based on both forest ecology (relations between organisms) and the silvics (behavior or response) of individual tree species. Silvicultural systems are applied to stands of trees (rather than to individual trees) composed of species that commonly grow together. By definition, silviculture is the practice of controlling forest composition, structure and growth to maintain and enhance the forest's utility for any purpose. Silviculture is applied to accomplish specific landowner objectives.

The following sections of this guide will cover a number of silvicultural systems and harvest methods separately to facilitate the discussion of sound silviculture. These systems, however, are often most effective when used in combination to best accommodate differences between and even within stands. The ability to adapt silvicultural systems to address multiple objectives is limited only by one's imagination and creativity, making the practice of sustainable forestry both an art and a science. Table 2-1 (see page 41) summarizes the array of regeneration harvest methods generally considered acceptable for the forest cover types in Wisconsin.

LANDOWNER GOALS AND OBJECTIVES

Silviculture and forestry practices are not ends within themselves, but rather a means of achieving specific objectives in a landowner's overall goal to manage a forest on a sustainable basis. The test of a silvicultural prescription or recommended forestry practice is how well it meets the landowner's sustainable forestry goals and objectives.

As noted previously, landowner goals may be varied, reflecting a variety of forest values and benefits. Some goals may have a higher priority than others, but it is important to remember they are often interrelated, and generally depend on sound forestry practices to be realized.

Goals can be achieved by accomplishing specific objectives. For example, a goal of periodic income or maintenance of wild turkey habitat might be achieved through an objective to regenerate an oak timber type through small shelterwood harvests spread over time. Think of a silvicultural prescription as a site-specific "action plan" to accomplish objectives.

In developing goals, landowners should realize that although specific site characteristics of their land could make some objectives unsustainable, there might be other viable courses of action to choose from. It is up to the forester and other resource professionals to identify all options open to the landowner, and to use as much flexibility as possible in designing a silvicultural prescription that best addresses the full range of landowner goals (see Chapter 9: Forest Management Planning for more information).

Figure 2-2: Landowners and resource managers should meet on-site prior to preparing a plan or conducting operations. Such meetings can help assure common understanding of landowner objectives, forestry prescriptions and site characteristics.

GOAL

A concise statement that describes a future desired condition normally expressed in broad, general terms that are timeless with no specific date by which the goal is to be achieved.

OBJECTIVE

Concise, time-specific statements of measurable, planned results that relate to overall goals.

Note: Generally, "goals" apply to an entire property and "objectives" to individual stands.

SITE EVALUATION AND STAND DELINEATION

Site capability determines what types of forestry practices are sustainable. A **site** is defined by the sum total of environmental conditions surrounding and available to the plants. A site is also a portion of land characterized by specific physical properties that affect ecosystem functions and differ from other portions of the land (Kotar, 1997).

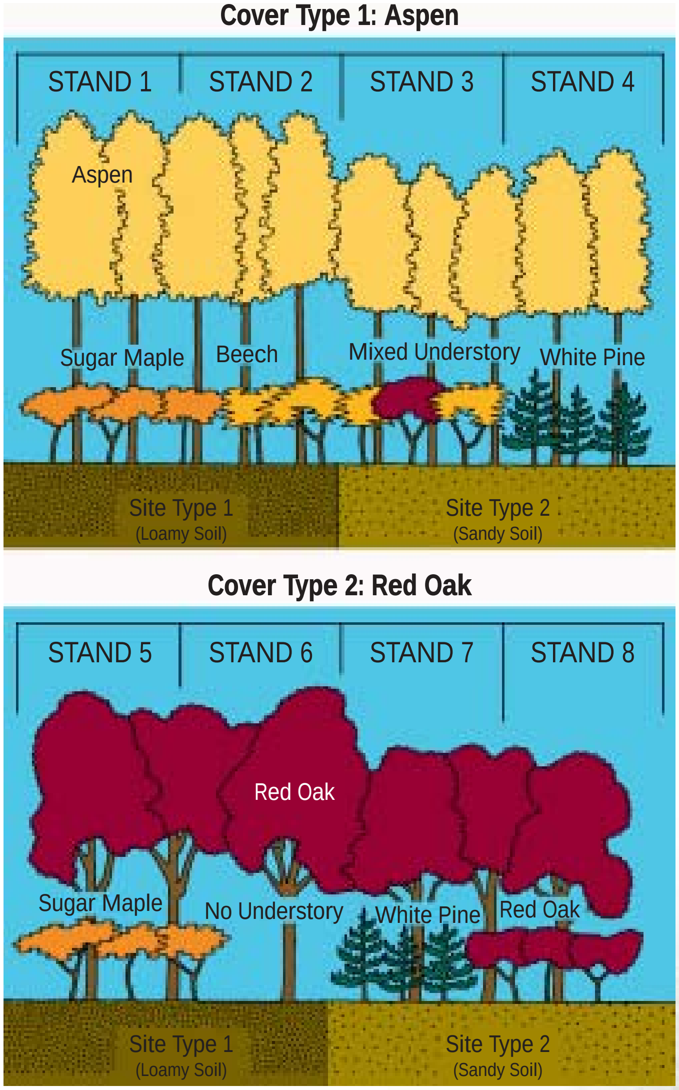

Figure 2-3: A schematic representation of two site types (loamy soil and sandy soil), two forest cover types (aspen and red oak), and eight stands. Each stand has unique composition and is defined by a specific combination of overstory and understory species. Each stand also can be considered as a unique ecological or silvicultural opportunity unit.

Forestry practices are carried out on a stand basis which determines where practices will occur. A **stand** may loosely be defined as a contiguous group of trees sufficiently uniform in species composition, arrangement of age classes, and general condition to be considered a homogeneous and distinguishable unit.

A stand is usually treated as a basic silvicultural unit. Stands are normally identified by the forest cover type involved (e.g., an “aspen stand,” a “northern hardwood stand,” or a “jack pine stand”). Cover types are discussed in more detail later in this chapter.

Forest stands are delineated through the use of aerial photographs, forest reconnaissance, inventory, and cruising. Sites are generally delineated based on soils, topography, landforms, geology, vegetation associations, and site index.

It is important to note that forest stands and sites often overlap each other. As illustrated in Figure 2-3, a single stand may occupy more than one site and a single site may support more than one stand.

Since a stand is the basic unit of silvicultural planning, care should be taken to ensure that it represents a uniform ecological opportunity unit. In other words, each specific site and stand combination has a unique set of silvicultural opportunities and constraints, which can be used to increase the number of outcomes available to the landowner. As shown in Figure 2-4 and Figure 2-5, defining stands by cover type and site type will facilitate the determination of management objectives.

Forest **site quality** is the sum total of all factors affecting the capacity to produce forests or other vegetation. Biotic and abiotic factors impact moisture, nutrient, and energy (light and heat) gradients, which determine vegetation growth and dynamics. Site quality affects tree growth, species composition and succession (plant community development). As site quality varies, so do forest management potentials and alternatives.

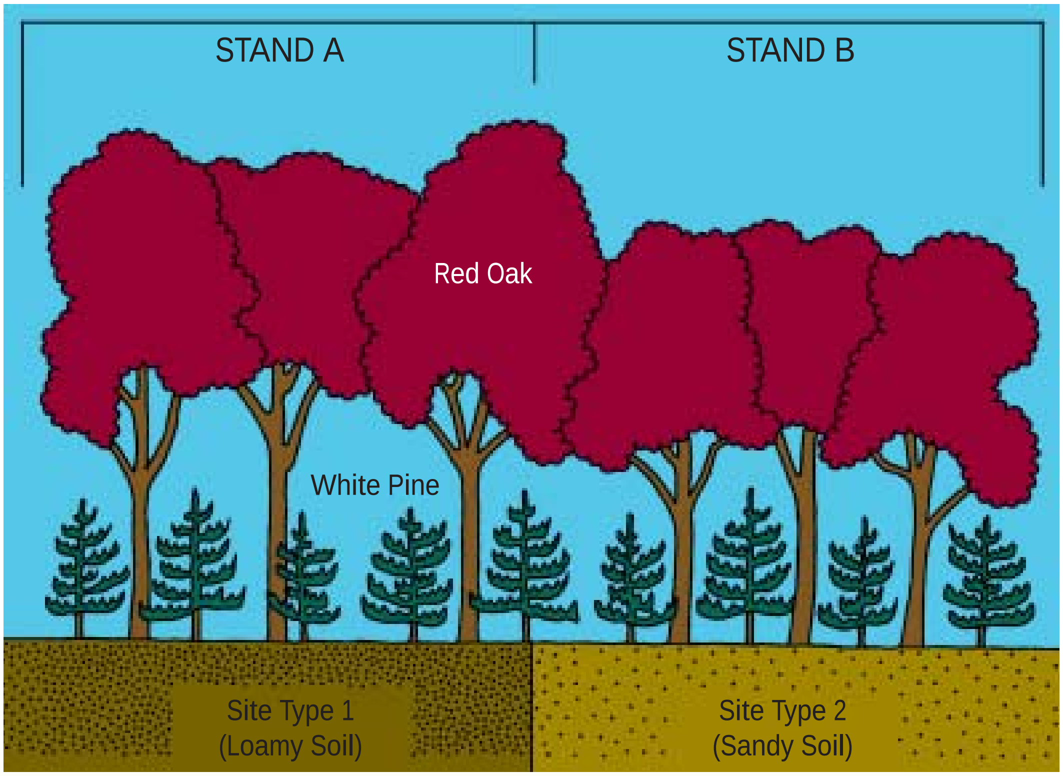

Figure 2-4: A single stand (red oak overstory with white pine regeneration) "straddles" two significantly different site types. Because ecological and silvicultural potentials differ for the two site types, the stand was split (A and B) to identify two ecological and silvicultural opportunity units.

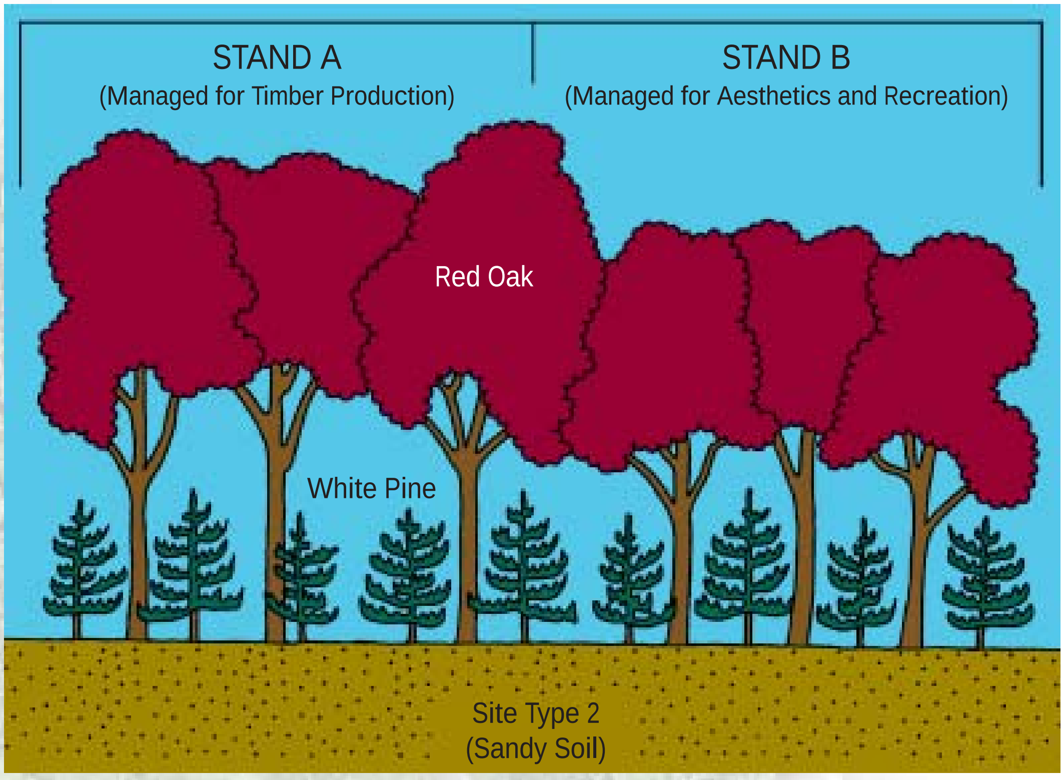

Figure 2-5: This stand is divided into two management units on the basis of different management objectives. E.g., in Stand A, oak will be harvested and white pine released to form a new crop, while in Stand B, oak overstory will be retained to provide a food source for wildlife and conditions for future old growth.

Forest site productivity is a measure of the rate of tree growth and overall wood volumes that can be expected on a given site. Productivity for a given species will generally vary between different sites as will productivity for different species on the same site.

There are direct and indirect ways to evaluate forest site quality and productivity:

- **Direct measures** of forest productivity such as historical yields and mean annual increment. These measurements are influenced by stand characteristics and may not be available.

- **Indirect measures** that relate environmental characteristics to tree growth and productivity are more commonly used. Indirect measures can be applied individually or in combination.

  - **Site Index:** Growth rates are measured and compared to tables that predict the height a particular species will attain at a given age.

  - **Vegetation Associations:** The number and relative density of key characteristic ground plants are measured, and a vegetative habitat type is identified. A great deal of inventory and other productivity date is available for each habitat type in Wisconsin.

  - **Physical Site Characteristics:** Examples include geology, landform, aspect, topography, and soil. These characteristics can be used to differentiate among types of sites that are significantly different with respect to their capabilities to support or produce different cover types or rate of tree growth. It is important to remember, however, that different combinations of individual site factors can result in functionally similar sites.

Regional site classification systems can provide tools to understand local site variability, impacts on site quality and productivity, and potential management alternatives.

Forest Cover Types and Silvicultural Alternatives

In a forested situation, tree species tend to occur in associations known as forest cover types. They range from a single tree species to several different species that commonly grow together on a specific site. The Department of Natural Resources recognizes 19 forest cover types statewide. It is important to understand that only a subset of these cover types will naturally occur on any given site, and, as a result, the range of sustainable management alternatives available are usually limited.

COMMON FOREST COVER TYPES FOUND IN WISCONSIN

Oak	Scrub oak	Northern hardwood
Aspen	White birch	Hemlock hardwood
Red pine	White pine	Central hardwoods
Jack pine	Red maple	Swamp hardwood
Cedar	Black spruce	Bottomland hardwoods
Walnut	Fir-spruce	Tamarack
Swamp conifer-balsam fir		

The forest cover type existing at a given point in time on a particular site will tend to change over time through the natural process of forest succession. Following a major disturbance such as fire or windstorm (or a silvicultural treatment designed to create similar conditions), a **pioneer community** normally invades a site. These communities (or forest cover types) are made up of sun-loving species able to rapidly establish themselves on an open, relatively competition-free, highly-disturbed site. Over time, the canopy begins to close and limit available sunlight, which results in other more shade-tolerant species becoming established.

As the original pioneer species are no longer able to compete, other **successional communities** better adapted to the changing microenvironment gradually replace them. A gradual transition to a number of different successional communities may occur as each gains a reproductive edge on the continually changing site conditions. At some point, after a long period free of disturbance, sites will transition to a potential **climax community** that is self-regenerating. This climax community will occupy the site until another disturbance creates conditions favoring re-establishment of a pioneer community (a major disturbance) or one of the earlier successional communities (a lesser disturbance).

In Wisconsin, these successional trends are fairly well understood for each ecological habitat type (site type). The pathways on some sites involve only a few stages; on others there may be several. Figure 2-6 is an example of the successional stages and trends on one particular site type.

An understanding of forest succession on a particular site can provide a great deal of useful information to a landowner evaluating potential management goals, and a forester developing the silvicultural prescriptions needed to achieve those goals. Referring to Figure 2-6, for example, one might reason:

- Only seven successional stages occur naturally on this site. Long-term management for quality northern hardwood or black walnut sawtimber, for example, would not be practical.
- Of the naturally occurring successional stages, some are currently more common at a landscape scale (as identified by the circles).
- Since a climax association is normally self-sustaining, maintaining an existing red maple, red oak, white pine, white spruce, and balsam fir type on this site would minimize regeneration costs.
- Based on the successional paths identified for this habitat type, the changes resulting from various levels of disturbance can be predicted. A partial removal of red pine overstory trees to release invading white pine, for example, would hasten the conversion from a red pine to a white pine timber type. On the other hand, a severe windstorm in a red oak-red maple stand might re-establish an aspen-white birch association for a period of time.
- Maintaining a pioneer or mid-successional stage would require a disturbance, such as active management, to overcome the natural tendency to convert to the next stage. Increasing light levels by maintaining a lower canopy density is needed to allow reseeding of the more light-demanding, earlier successional stages. Marking criteria would have to focus on releasing preferred species from more shade-tolerant species to ensure survival.
- Reversing the trend and going back to a previous successional stage would generally require a significant disturbance. Even-aged management would normally be needed to create conditions favorable for re-invasion by pioneer successional stages like aspen and white birch. Prescribed fire or mechanical scarification may be required to favor jack pine. Site preparation and planting would probably be needed to re-establish red pine. In general, the further succession is set back, the more disturbance and effort will be required.

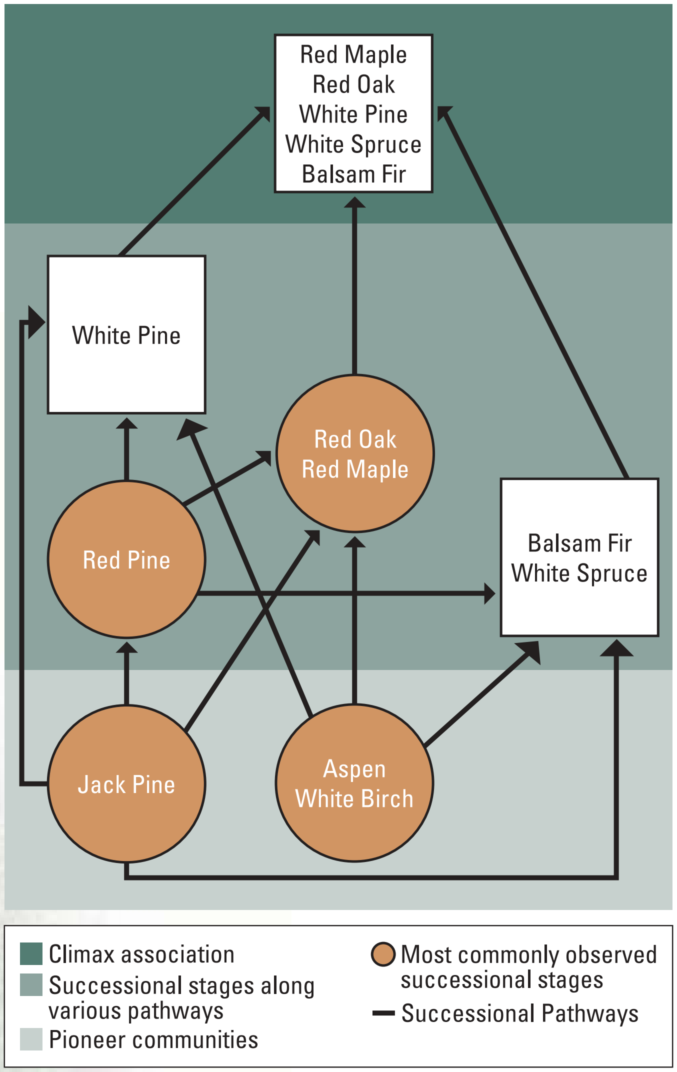

Figure 2-6: A generic example of the information available relative to the most commonly observed successional stages and probability of succession for a particular site type.

SILVICULTURAL SYSTEMS OVERVIEW

A **silvicultural system** is a planned program of vegetative manipulation carried out over the entire life of a stand. All silvicultural systems include three basic components: **harvest, regeneration and tending**. These components are designed to mimic natural processes and conditions fostering healthy, vigorous stands of trees. Typically, silvicultural systems are named after the regeneration method employed to create the conditions favorable for the establishment of a new stand.

A **harvest method** differs from a simple harvest cut in that it is specifically designed to accomplish two objectives – removal of trees from the existing stand, and the creation of conditions necessary to favor regeneration and establishment of a new stand. The method selected depends on the species to be regenerated or established in the new stand. Harvest methods vary from the complete removal of a stand in a single cut or in stages over several years, to the selection of individual trees or groups of trees on a periodic basis.

A **regeneration method** is a process by which a stand is established or renewed. The various methods include: 1) removal of the old stand; 2) establishment of a new one; and 3) any supplementary treatments of vegetation, logging residue, or soil applied to create conditions favorable for the establishment of reproduction. There are two general regeneration techniques:

- **Natural regeneration systems** rely on natural seeding or root/stump sprouts and are generally carried on concurrently with the harvest process. In some cases, additional follow-up activities (e.g., scarification, understory competition control, slash treatment, or prescribed fire) may be necessary.
- **Artificial regeneration systems** depend on the planting of tree seedlings or seeds. Generally, planting occurs on non-forested land or following complete removal and harvest of a forest overstory and results in an even-aged stand. Examples of artificial regeneration systems are:
  - **Afforestation:** Establishing a new forest on non-forested land.
  - **Reforestation and Conversion:** Forest type conversion when the desired species is not present or is inadequately represented to provide sufficient seed or vegetative reproduction.
  - **Reforestation and Re-establishment:** Forest type re-establishment when the desired species are difficult to regenerate, and it appears to be more efficient to utilize artificial regeneration than to depend on natural regeneration.

Table 2-1 (see page 41) shows the regeneration harvest methods described in this chapter as generally accepted for application to Wisconsin forest cover types.

Tending includes a variety of intermediate treatments that begin after regeneration is established and are implemented as needed throughout the rotation of a forest stand. These treatments include pruning, release, thinning/improvement, and salvage/sanitation. They are done to improve stand composition, structure, growth, quality and health, and to produce specific benefits desired by the landowner. Some tending operations are non-commercial (e.g., pruning, early release of crop trees, precommercial thinning), requiring outright investment by the landowner, and can be collectively referred to as timber stand improvement (TSI). Other tending operations, such as commercial thinning, can generate revenue for a landowner. Intermediate silvicultural treatments are discussed in detail in Chapter 16: Intermediate Silvicultural Treatments.

Several different silvicultural systems are discussed in detail in the next section of this chapter, emphasizing the particular rationale and goals of each. Although each system is discussed separately to aid in understanding, **it should be understood they are commonly used in combination to best accommodate site differences between and within stands.** Flexibility and imagination are key in tailoring silvicultural systems to address the host of values inherent in sustainable forest management.

SILVICS, THE BASIC BUILDING BLOCKS OF A SILVICULTURAL SYSTEM

EXAMPLES OF SELECTED SILVICAL CHARACTERISTICS FOR THREE COMMON WISCONSIN TREE SPECIES

	Aspen	Northern Red Oak	Sugar Maple
Pollination	March - April	April - May	March - May
Seeds Mature	May - June	September - October of the next year	Fall
Seed Dispersal	Immediately after ripening. Wind and water long distance dissemination.	September - December Gravity and animal dissemination.	Fall Wind dissemination up to 330 feet.
Good Seed Years	Every 4 - 5 years	Every 2 - 5 years	Every 1 - 5 years
Germination	Immediately following dissemination. No dormancy. 32 - 95ºF. Bare soil required.	Spring, 2 years following pollination. Mixed mineral/ humus soil preferred.	Spring, 1 year following pollination. Best at 34ºF. Bare soil not required.
Seedling Development	6 - 24" height and 8 - 10" taproot development in the first year in full sunlight.	Moderate height growth. Dieback common. Rapid taproot development.	Best growth in 30 - 90% full sunlight. Sensitive to moisture stress.
Vegetative Reproduction	Vigorous root suckers following fire or cutting. 4 - 6' height growth in first year.	Stumps sprout readily and can average 24" of height growth per year.	Stumps sprouting decreases with increasing tree size.
Shade Tolerance	Intolerant. Pioneer species.	Mid-tolerant. Maximum photosynthesis occurs at 70% shade.	Very tolerant.
Typical Rotation Age	45 - 70 years	60 - 150 years	80 - 175 years
Max. Life Expectancy	100 - 150 years	300 - 400 years	300 - 400 years

For a complete listing of all Silvical Characteristics for all Wisconsin trees, see the following web site:
http://na.fs.fed.us/spfo/pubs/silvics_manual/table_of_contents.htm

Another key factor to keep in mind is that all harvests are not necessarily part of a regeneration system. In some cases, a harvest is specifically designed to capture the value of trees that might otherwise be lost. An example would be a situation where past cutting practices or natural events have left many mature trees scattered over an otherwise immature stand. Waiting for the scheduled regeneration harvest of the younger stand would likely result in loss of valuable forest products. As a result, a harvest might be carried out as part of an intermediate or salvage operation specifically to remove all or a portion of the older trees. Even though such harvests are not part of the overall regeneration system being applied to the primary stand, they should be compatible with overall long-term silvicultural objectives.

Remember, too, that silvicultural systems are developed based on the characteristics of forest cover types and a consideration of site factors. Specific treatments within a system should be modified to accommodate any special requirements.

Some of the key considerations in the selection of a silvicultural system include:

- **Shade Tolerance:** The ability of a given tree species to survive and grow in low light conditions under a forest canopy is referred to as its shade tolerance. This silvicultural characteristic is one of the most important considerations in the selection of a silvicultural system. Once established, most trees will maximize vigor and growth in near full sunlight. However, the amount of sunlight required for regeneration, early survival and different growth rates varies between tree species. Some species require full sunlight for their entire life cycle while others benefit from some protection in the regeneration and early establishment phases, only requiring full sunlight later to maintain growth and vigor. Still other species are able to regenerate and develop under very shady conditions, and use that ability to effectively compete with more sun-loving species.

SHADE TOLERANCE OF WISCONSIN TREE SPECIES

Shade-tolerant

Able to reproduce and grow under a dense canopy.

Sugar maple[1]	Beech[1]	Basswood
Red maple	Boxelder	Ironwood
Musclewood	Hemlock[1]	Balsam fir[1]
Black spruce	White spruce	White cedar

Mid-tolerant or Intermediate

Reproduce best under a partial canopy which admits limited sunlight.

Red oak	White oak	Bur oak
Black oak	Hickories	Swamp white oak
Elms	Hackberry	Silver maple
Yellow birch	Ashes	White pine

Shade-intolerant

Light demanding species that reproduces best in full sunlight.

Aspen[2]	White birch	Balsam poplar
Black cherry	Butternut	Northern pin oak
Black walnut	River birch	Jack pine[2]
Red pine	Tamarack	Eastern cottonwood

1 Most tolerant species *2 Least tolerant species*

Note: Tolerance levels for a given species may vary during its life cycle.

- **Age Distribution and Stand Structure:** The age difference between individual trees within a particular stand varies. Some cover types typically regenerate all at once following a major disturbance (e.g., fire, wind events, insect and disease activity, past cutting, etc.). Others regenerate as groups following smaller disturbances, while still others regenerate almost continuously as individual trees die and create openings. As a result, the trees in some stands are essentially all the same age, while in others age varies widely. These age differences within a stand are often reflected by differences in tree heights and diameters. Trees in an even-aged stand tend to mature at the same time, while trees in an uneven-aged stand tend to mature as groups at distinct intervals or as individual trees on a relatively continuous basis.

- **Stand Condition:** A species composition, age, structure, quality, health and vigor, and spatial distribution of the trees (and other plants) within a stand must be carefully considered. Silvicultural guidelines and standard management systems generally are developed for typical or average conditions.

  In some cases, however, stands may exhibit a combination of low vigor, poor health, excessive logging damage, low stocking, inappropriate age or stand structure, low tree quality, compacted or eroded soils and/or other abnormal characteristics. These stand conditions typically result from abuse, neglect or improper management practices such as high grading or diameter limit cutting. Such **degraded stands** may require modification of a standard silvicultural system to address specific stand and site conditions. Sometimes, intermediate treatments such as a series of improvement cuttings and free thinnings, can restore degraded stands to acceptable and productive conditions. Other times, when degradation is extreme, regeneration methods may be needed to initiate development of an entirely new stand. The appropriate rehabilitative treatments may not be those generally recommended for the cover type, or may be applied at unusual times or in an unusual sequence.

Figure 2-7: Pulling garlic mustard before seeds set, as demonstrated by a Wisconsin Conservation Corps crew member, is an effective method to control this non-native invasive plant.

- **Understory Competition:** The relative competitive abilities of desired species, other species, and undesirable species (trees, shrubs, and herbs that are present or could invade) should be considered. Key species-specific considerations include regeneration strategies, shade tolerance, response to release, and growth rates across variable site and stand conditions. Different silvicultural methods and systems can be utilized to encourage or discourage a particular species.

  The presence of **non-native invasive plant and animal species** can limit the success of potential silvicultural systems. The aggressive competitive abilities of some plants can interfere with desired regeneration and development. Some non-native invasive species can directly attack and damage desired species. Specific silvicultural methods and systems must be designed to discourage the growth and spread or ameliorate the impacts of such species.

- **Seed Production, Dissemination and Predation:** If regeneration is dependent on seed from the existing stand, a harvest may have to be timed to coincide with periodic seed years. Tree selection, sale shape, and follow-up seedbed preparation treatments must enhance seed dissemination, and discourage seed predation.

- **Seedbed Characteristics, Germination Requirements and Early Survival:** Some species require a mineral seedbed for germination while others are able to penetrate the litter on the forest floor and germinate in undisturbed areas. Still other species germinate best on seedbeds composed of a combination of mineral soil and humus. The germination temperature and the sunlight requirements for early survival may also be more specific for some species than others.

- **Seedling Establishment and Competition Control:** In some cases, overstory shade is needed to protect desired seedlings from excessive heating and drying during the establishment phase and/or retard the development of competing species. In others, full sun is required to maximize growth and the ability of the desired species to outperform competing species.

- **Quality Considerations:** In stands managed for high-quality sawtimber, overstory shade levels must be carefully controlled to minimize sunscald and epicormic branching and forking, while at the same time maximizing tree form and merchantable height.

EVEN-AGED SILVICULTURAL SYSTEMS

Even-aged management systems are normally used to harvest, regenerate and tend sun-loving forest cover types that grow poorly or will not regenerate in their own shade. The cover types adapted to these systems are generally those accustomed to regeneration and rapid domination of a site following a catastrophic disturbance, such as a fire or major windstorm. Stands normally consist of trees at or near the same age. Even-aged systems are also applied to cover types dominated by shade-tolerant species when the intent is to focus on the less-tolerant component of the stand. Portions of even-aged management systems, specifically the intermediate thinning regimes, may also be used in the early stages of young northern hardwood stands to facilitate a long-term conversion to the uneven-aged system.

Even-aged Harvest and Regeneration Methods

Light requirements, growth rates and reproductive characteristics of the species to be regenerated govern the degree of overstory removal at the time of harvest. Competing vegetation and site characteristics are additional factors. The following are the generally accepted even-aged regeneration methods used in Wisconsin.

EVEN-AGED REGENERATION METHODS USED TO PARTIALLY SIMULATE THE DEGREE OF STAND MORTALITY THAT WOULD NORMALLY FOLLOW A MAJOR NATURAL DISTURBANCE SUCH AS A FIRE OR MAJOR WINDSTORM

These methods are primarily used with intolerant species such as aspen, red pine or jack pine that require full sunlight to ensure complete regeneration and optimum development.

- **Coppice:** (Figures 2-8 through 2-11) A method designed to naturally regenerate a stand using vegetative reproduction. The overstory is completely removed.

  Generally, there is no residual stand left as the residual can interfere with the regeneration, and is not necessary to shelter the regenerated stand. This method differs from the other even-aged regeneration systems (clearcut, seed-tree and shelterwood) in that the regenerated stand is derived from vegetative reproduction rather than a seed source.

Figure 2-8: This aspen stand was harvested one year ago using the coppice regeneration method. Red pine "standards" were retained to enhance visual diversity. Abundant aspen from vegetative reproduction is now established.

Figure 2-9 (Coppice A): A 50-year-old aspen stand with smaller numbers of northern red oak, red maple and white pines mixed in (the understory has been reduced for image clarity).

Figure 2-10 (Coppice B): An aspen stand immediately following a clearcut/coppice regeneration harvest showing tree stumps, coarse woody debris and scattered advanced natural regeneration.

Figure 2-11 (Coppice C): A stand of dense coppice-origin aspen sprouts 10 to 15 years after the initial harvest.

Figure 2-12: This central Wisconsin stand of mixed jack pine and "scrub" oak was clearcut within the past year.

- **Clearcut:** (Figure 2-12) A method used to regenerate a stand by the removal of most or all woody vegetation during the harvest creating a completely open area leading to the establishment of an even-aged stand. Regeneration can be from natural seed produced by adjacent stands, trees cut in the harvesting operation, direct seeding, or replanting.

  This method differs from the seed-tree and shelterwood methods in that no trees are left in the cut area for seeding purposes. Rather, the seed source is from outside the cut area or from felled tops of harvested trees.

- **Seed-tree:** (Figures 2-13 and 2-14) A method designed to bring about natural reproduction on clearcut harvest areas by leaving enough trees singly or in groups to naturally seed the area with adequate stocking of desired species in a reasonable period of time before the site is captured by undesirable vegetation. In this method, only a few trees (typically three to 10 per acre) are left and the residual stocking is not enough to sufficiently protect, modify or shelter the site in any significant way. Seed-trees may be removed after establishment or left indefinitely.

  This method differs from the coppice method in that regeneration comes primarily from seed rather than sprouts. It differs from a clearcut in that the seed source for regeneration is from residual trees within the harvest area rather than outside the cut area, or relying on seed existing on or in the ground. It differs from a shelterwood in that the residual stocking is too sparse to modify the understory environment for seedling protection.

Figure 2-13 (Seed-tree A): A mature forest of mostly white pines mixed with smaller amounts of northern red oak and red maple. Seed-tree harvesting is one method used with even-aged species that require full sunlight for regeneration. All trees in such stands are generally ready for harvest at the same time, but sufficient advanced regeneration is not usually present.

Figure 2-14 (Seed-tree B): White pine residual following a seed-tree regeneration harvest leaving about three to 10 trees per acre as a seed source to renew the stand.

EVEN-AGED REGENERATION METHODS USED TO PARTIALLY MIMIC NATURAL DETERIORATION OF THE OVERSTORY OVER TIME

These methods are tailored to more tolerant species that require partial shade and/or a seed source for optimum regeneration, but once established need full sunlight for survival and full development (such as white pine and oak).

- **Shelterwood:** (Figures 2-15 through 2-20) A method used to regenerate a stand by manipulating the overstory and understory to create conditions favorable for the establishment and survival of desirable tree species. This method normally involves gradual removal (usually in two or three cuts) of the overstory. The overstory serves to modify understory conditions to create a favorable environment for reproduction and provide a seed source. A secondary function of the overstory is to allow further development of quality overstory stems during seedling establishment. The most vigorous trees are normally left as the overstory, and the less vigorous trees removed.

A successful shelterwood harvest often requires the removal of intermediate or suppressed saplings and poles (often of less desirable species such as elm, ironwood or red maple) because the smaller understory trees will suppress development of vigorous seedlings of the preferred species.

Initial shelterwood cuttings resemble heavy thinnings. Natural reproduction starts under the protection of the older stand, and is finally released when it becomes desirable to give the new stand full use of the growing space. At that point, the remaining overstory is completely removed.

This method differs from clearcutting and coppice methods in that the next stand is established on the site before overstory removal. It differs from a seed-tree cutting in that the overstory serves to protect the understory as well as distribute seed. Finally, an even-aged shelterwood harvest differs from uneven-aged selection methods in that it promotes an even-aged stand structure.

Figure 2-15: May apples and other ground vegetation have begun to resprout following the first shelterwood cut (seed cut) in this red oak stand. Logging slash was removed and the ground scarified to provide improved conditions for light-demanding oak acorns to germinate.

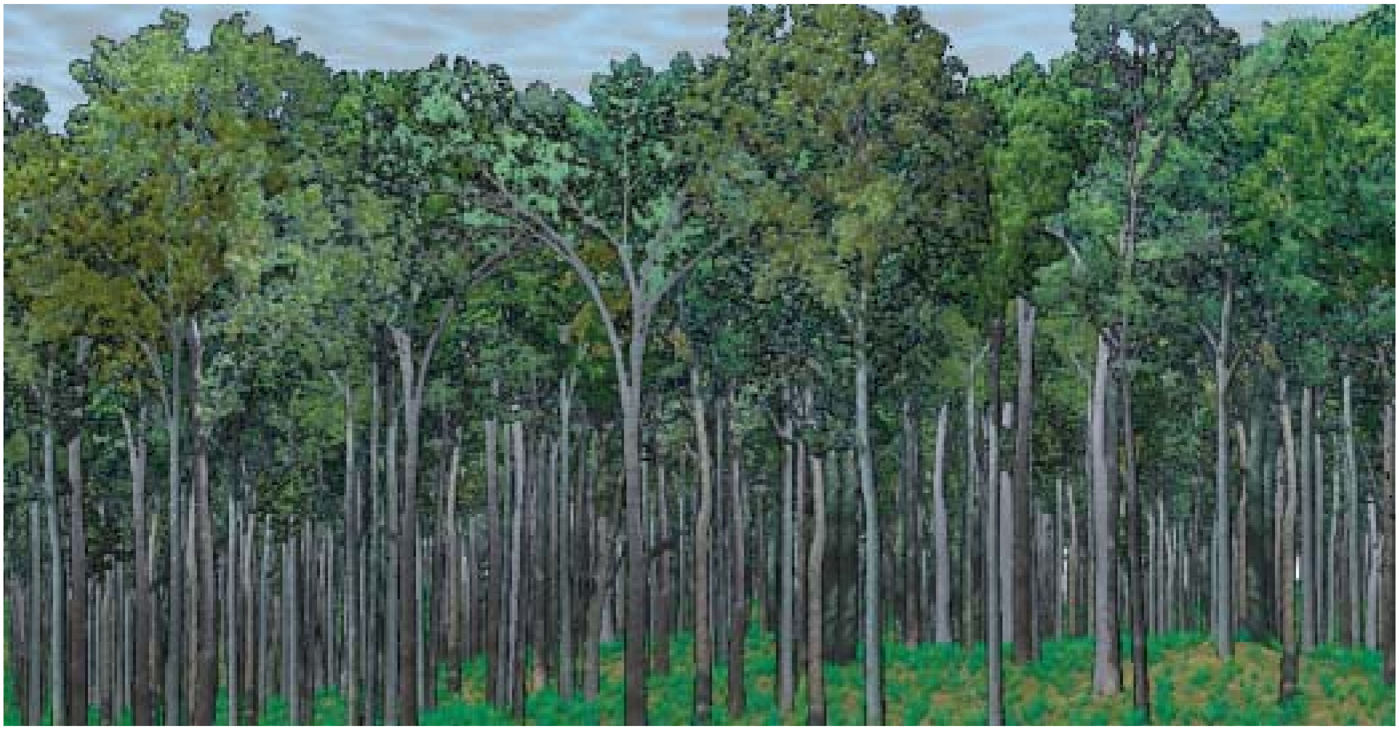

Figure 2-16 (Shelterwood A): A dense stand of mature oak sawtimber and associated hardwoods before harvest. Notice the uniformity in size and age in the overstory, and the lack of regeneration.

Figure 2-17 (Shelterwood B): An oak forest soon after the first stage of a shelterwood harvest. The overstory has been opened up to allow sufficient light penetration for seed germination. Enough shade has been retained to prevent excessive drying of the seedbed and enhance early survival and establishment of the new seedlings. (Note: In some situations, post-harvest treatment of the understory with herbicides or mechanical scarification may be needed to control competition or prepare the seedbed.)

Figure 2-18 (Shelterwood C): The same stand after five years. Notice the regeneration developing as a result of the increased light penetration.

Figure 2-19 (Shelterwood D): An oak stand after the second stage (overstory removal) of a shelterwood harvest. After approximately 10 years, adequate regeneration is fully established, and the overstory has been removed to provide the added sunlight needed to maximize growth and development.

Figure 2-20: Natural regeneration after a shelterwood harvest has developed into an excellent stand of red oak poletimber, 30 years later, on the Hardies Creek Stewardship Forest in Trempealeau County.

- **Overstory Removal:** A method used to mimic the natural deterioration of the overstory but at an accelerated rate in situations where adequate regeneration is already established. The entire stand overstory is removed in one cut to provide the release of established seedlings and saplings. This method has been referred to as a natural shelterwood or a one-cut shelterwood.

  Overstory removal results in an even-aged stand structure as opposed to uneven-aged structure. It differs from the clearcut and the coppice regeneration methods in that seedling and sapling regeneration is established prior to the overstory removal. It differs from the shelterwood and seed-tree methods in that no manipulation of the overstory is needed to establish regeneration.

  Overstory removal can be applied to all forest stands being managed on an even-aged basis if desirable advance regeneration is well-established. Cover type specifics and applicability of overstory removal are addressed in appropriate cover type chapters of the Wisconsin DNR *Silviculture and Forest Aesthetics Handbook, 2341.5*. General considerations in the application of the overstory removal method are:
  - Overstory health, condition and composition
  - Potential risk of raising the water table on wet sites
  - Adequate stocking, distribution, vigor and desirability of established, advanced regeneration
  - Site capability
  - Existing and potential competition, including exotic species

All the even-aged methods have **variants with reserves** involving scattered trees left throughout the harvest area or in groups or clumps. Individual trees or groups of trees left uncut on a long-term basis will hamper the growth of seedlings adjacent to them, but regeneration should be adequate as long as the reserves do not exceed approximately 20 percent crown density. With such reserves, even-aged systems can be managed as two-aged systems on a long-term basis.

In most cases, the goal of an even-aged silvicultural system is to naturally regenerate a species already present in the stand. Depending on the species involved, additional activities may be required to ensure that its germination and growth requirements are met. These may involve the use of prescribed fire, disking and other forms of scarification to expose a mineral soil seedbed to enhance seed germination and survival. Where natural regeneration is insufficient or in cases where the desired species was not present in the harvested stand, tree planting or direct seeding may be required.

Even-aged Tending Methods

Tending operations implemented in young stands usually are non-commercial. **Timber stand improvement (TSI)** generally includes the **intermediate treatments** pruning and release. **Pruning** is usually applied to improve timber quality and value, although it can also be utilized to control disease, improve aesthetics, or improve stand accessibility. **Release** treatments are designed to free young trees from undesirable competing vegetation to improve stand composition, growth and quality.

Thinning and improvement are intermediate treatments implemented in older stands with larger trees that often offer commercial opportunities. **Thinning** entails the removal of trees to temporarily reduce stocking and concentrate growth on the more desirable trees. Thinnings are applied primarily to improve diameter growth, manipulate structure, enhance forest health, recover potential mortality, and increase economic yields. **Improvement cutting** is the removal of less desirable trees of any species primarily to improve composition and quality. Typically, improvement is applied coincidentally with thinning.

Specific applications of intermediate treatments depend on landowner goals and objectives, economic constraints and opportunities, site capability, stand development, and the silvics/ecology of the desired species and their competitors. Intermediate silvicultural treatments are discussed in detail in Chapter 16: Intermediate Silvicultural Treatments.

In most even-aged stands, intermediate treatments are generally applied relatively consistently across the stand. These thinning practices can be modified (spatially) and temporarily applied in even-aged stands where the long-term management objective is conversion to uneven-aged management. For example, in even-aged small sawtimber-sized northern hardwood stands, even-aged thinning guides can be applied to most of the stand, however, some regeneration gaps can be created to initiate the development of an uneven-aged structure. Following one or more of these modified even-aged thinnings with canopy gaps, later operations are then based on uneven-aged selection management guidelines (simultaneous thinning, harvest and regeneration).

Figure 2-21 and 2-22: The importance of tending an even-aged stand is illustrated by comparing these two plots in the famous Star Lake thinning experiment started by Fred Wilson with red pine planted in 1913. Figure 2-21 (left) shows the poor growth and mortality in the plot that was never thinned. The adjoining plot, Figure 2-22 (right), shows the impact that periodic thinnings (every five to 10 years starting in 1943) can have on red pine growth and quality.

Even-aged Harvest Considerations

Under even-aged silvicultural systems, entire stands are harvested all at once or over a relatively short period when they reach a given age. The term rotation is used for the period of years required to grow timber stands to a specified condition of maturity. The age of the stand at the end of the rotation period when it is normally harvested is called the **rotation age**.

Traditional rotation ages are set at a point in time when average annual growth reaches its maximum. Beyond that age, stands grow more slowly. Decay and tree mortality may begin to increase. This rotation age varies by species and site, and is normally established for each individual species reflecting prevailing regional or local conditions. Eventually a stand will reach its pathological rotation age, at which time insect and disease activity result in such extensive decay and mortality that harvesting of the stand is no longer economically viable. At the stand level, natural mortality of the overstory becomes significant. Regeneration of the current overstory may also become difficult due to natural succession and loss of seed sources.

Rotation length will vary with a number of factors:

- **The average growth rate and life span of the species involved.** A typical rotation age for a stand of aspen, for example, is 45 to 60 years. A typical rotation age for an oak stand may be two to three times as long.
- **The type and quality of product desired.** Pulpwood takes a shorter time to produce than sawlogs, which must be larger in diameter. High quality sawlogs and veneer logs require more time since they are typically grown to still larger diameters and at higher density levels.
- **Economic considerations.** Changes in supply and demand in general, specific customer requirements, market values, and internal infrastructure demands can all result in modified rotation ages.
- **Site productivity.** More productive sites support increased growth rates for a longer period of time. As a result, the period of positive mean annual growth is also extended, increasing the optimum rotation age. Different rotation lengths are typically employed across the range of site productivity.

Figure 2-23: Red pine is a good example of a species amenable to modification of rotation age to reflect site productivity, product goals, and landowner non-timber objectives.

- **Insect and disease concerns.** The level of mortality and decay caused by insects and disease is a prime factor in net growth. Insect and disease outbreaks can significantly reduce stand growth, and in extreme cases, cause such extensive mortality that they determine rotations. As stands age, the risk of sudden, extensive mortality increases.
- **Landowner goals.** Rotation ages can be extended to enhance non-timber resources if a landowner is willing to accept reduced growth rates and potentially forgo some timber revenues. In some cases, these extended rotations can enhance the supply and value of some high quality timber products such as sawtimber and veneer. Just as stands can be held for some time after the normal rotation age, they can also be harvested for a period prior to the normal rotation age. This harvest period can be used to space harvests over time, divide or combine stands to meet other landowner goals, manage the flow of timber income, or deal with other supply and demand economic constraints.

UNEVEN-AGED SILVICULTURAL SYSTEMS

Uneven-aged management systems are normally used to harvest, regenerate and tend forest cover types that will regenerate and grow under their own shade. Stands managed under uneven-aged systems are normally comprised of three or more age classes. These cover types are adapted to regenerate under partial canopies following minor disturbances like individual tree mortality, or a moderate disturbance such as a wind storm that would damage up to one third of the stand. Uneven-aged systems are designed to mimic such disturbances.

Even shade-tolerant species grow most vigorously in relatively free-to-grow conditions with full sunlight, assuming other growth requirements like soil moisture, are met. As a result, regeneration and most vigorous growth typically occur in small- to medium-sized gaps (small openings). The number and size of gaps created through uneven-aged management are dependent upon species composition, acreage regulation, and tree rotation age or size. Normally, these systems are used to manage stands containing mixed trees of all ages, from seedlings to mature trees. They are also used to convert even-aged stands into an uneven-aged structure.

Figure 2-25: Species Desirability

Uneven-aged Harvest and Regeneration Methods

Stand regeneration is achieved by periodically manipulating the overstory and understory to create conditions favorable for the establishment and survival of desirable tree species. Thinning, regeneration and harvesting usually occurs simultaneously. The harvested trees are essentially replaced by growth on the younger trees left in the stand. These silvicultural systems are designed to maintain an uneven-aged stand condition, while manipulating the multi-age and multi-size structure of the overstory to facilitate continual recruitment and development of quality growing stock.

With the uneven-aged silvicultural system, the tree selection decision (to cut or leave) considers a number of factors as illustrated in Figures 2-24 through 2-26.

Figure 2-24: Tree Quality

Figure 2-26: Desired Age and Size Class Distribution

The following are generally accepted uneven-aged natural regeneration systems used in Wisconsin:

- **Single-tree Selection:** (Figures 2-27 and 2-28) Individual trees of various size and age classes are periodically removed to provide space for regeneration, and promote the growth of remaining trees. Each regeneration opening (gap) covers an area equivalent to the crown spread of a single large tree that has been removed. Individual trees are selected for removal from all size classes (to achieve desired residual density levels) following recognized order of removal criteria based on tree risk, vigor, quality, and spacing.

The goal, particularly in the northern hardwood cover type, is to achieve an optimum distribution of size and age classes so each contains a sufficient number of quality trees to replace those harvested in the next larger size class. Specific selection criteria vary slightly with the particular species makeup of the stand involved (see the Wisconsin DNR *Silviculture and Forest Aesthetics Handbook, 2431.5* or an appropriate management guide).

Figure 2-27 (Single-tree Selection A): An uneven-aged northern hardwood stand which has not been harvested in 15 years. The basal area is approximately 120 square feet per acre.

Figure 2-28 (Single-tree Selection B): The same stand following a single-tree selection harvest. Trees have been removed from across the range of age and size classes to maintain an uneven-aged structure. The residual basal area is about 84 square feet per acre.

- **Group Selection:** Trees are periodically removed in small groups to create conditions favorable for the regeneration and establishment of new age classes. In general, the openings created may range in size from fairly small 0.02 acre (30' diameter circle) up to one-half acre (166' diameter circle or approximately two tree lengths). In northern hardwood management, gaps are generally less than one-tenth acre. Smaller openings favor regeneration of more-tolerant species, while larger openings favor mid-tolerant species.

  In general, stands dominated by large crowned tolerant species (such as sugar maple, beech and hemlock) do not require the creation of large openings to provide sunlight for regeneration, and individual trees are harvested as they mature using the single-tree selection method. However, some of the less-tolerant species commonly associated with sugar maple (such as basswood, yellow birch and ash) benefit from the use of the group selection method to enhance recruitment and growth of new seedlings. One-quarter to one-half acre gaps may also have potential application in the management of uneven-aged stands of mid-tolerants like red oak and white pine on some sites. Potentially, most-tolerant to mid-tolerant species can be managed by applying variations of the selection regeneration method, if appropriate steps are taken to control competition.

  In general, stands managed under uneven-aged systems regenerate as a result of manipulation of light levels during the harvest process. In some cases, non-commercial removal of additional cull trees or poorly formed saplings may be needed to further enhance regeneration in specific areas which are not opened up through the normal selection process.

Uneven-Aged Tending Methods

In uneven-aged silvicultural systems, tending operations are not as clearly distinguished from harvest and regeneration operations as in even-aged systems. Harvest and regeneration are perpetual operations, rather than occurring once during a stand's rotation, so tending must also be integrated and not temporally separated. In addition, uneven-aged stands often have a spatially patchy age structure that may require patchy applications or variations of intermediate treatments.

Release treatments are designed to free young trees from undesirable competing vegetation to improve stand composition, growth and quality. These **timber stand improvement (TSI)** treatments can be applied to regeneration openings created by single-tree or group selection systems, although costs associated with the location and treatment of scattered regeneration patches may be prohibitive. They are probably most needed and feasible where the objective is to facilitate the survival, growth, and development of seedlings and saplings of mid-tolerant species growing in larger openings created through application of the group selection system. In addition, as canopy crowns expand over time, previously created regeneration gaps may need to be re-opened or expanded to maintain the vigorous growth of young trees; this release operation can be conducted concurrently with other periodic cutting operations.

Thinning is an intermediate treatment that entails the removal of trees to temporarily reduce stocking to concentrate growth on the more desirable trees. Thinnings are applied primarily to improve diameter growth, manipulate structure, enhance forest health, recover potential mortality, and increase economic yields. **Under the uneven-aged silvicultural system, thinnings are implemented concurrently with periodic harvest and regeneration operations.** Stands are normally re-entered on an eight- to 20-year cutting cycle depending on landowner objectives, economic constraints and opportunities, site quality, tree growth rates, stand development, and the silvics of the desired species. Specific target stand stocking levels (density management) by size and age class are very important to tree growth and quality development. Often, small groups or patches of essentially even-aged trees can be recognized and treated. Tree selection is based on a recognized order of removal that considers tree risk, tree vigor, crop tree release, species composition, and spacing. Additional criteria can also be employed to enhance wildlife habitat, biodiversity, water quality, and aesthetic values. Temporary **improvement cutting** may be needed to improve composition or quality in stands that have been previously unmanaged, neglected or poorly managed.

Figure 2-29: When the uneven-aged system is used, an optimum maximum tree diameter class (the target diameter) is determined for each stand.

Uneven-aged Harvest Considerations

Harvests in uneven-aged stands occur regularly. The normal cutting cycles range from eight to 20 years. The interval is based on site quality, growth rates, removable volumes, and landowner goals relative to each stand.

Individual trees are removed from each size (or age) class as needed to achieve the desired level of stocking. When selecting which trees to remove within each diameter class, the primary factors considered are risk, vigor, quality, and spacing. In addition, an optimum maximum diameter class is determined for each stand based on the following considerations:

- **Site Productivity:** Higher quality sites normally allow trees to be carried to a larger diameter before growth rates decline significantly and degrade/decay becomes a major factor in tree value.

- **Average Growth Rates and Life Spans of the Species Involved:** Stands managed under uneven-aged silvicultural systems normally contain a variety of different species, each having a different optimum maximum diameter class.

- **Type and Quality of Products Desired:** A decision to focus on sawtimber, veneer or both will influence the selection of an optimum maximum diameter class.

- **Balancing Risk and Economic Value:** As a particular high quality crop tree gets larger, it becomes more economically valuable. The value increase is due to more than just the additional volume accumulated as the tree grows. As a tree passes though a number of threshold diameters, it increases in grade and value dramatically. The values of sawlogs depend more on grade than volume. Larger diameters are required for the higher grades, which can bring two to three times the value of lower grade logs. Attaining veneer size can result in another major increase in tree value. The decision to leave a particular large valuable tree uncut must be weighed against the uncertainty of it still being alive and healthy 10 to 15 years later, when the next periodic harvest will be done. If it survives, it may increase significantly in timber value; if it is damaged or dies, that value could be lost. The evaluation of tree risk and vigor is critical to the determination of individual tree rotation.

- **Landowner Goals:** Maximum diameter classes can be increased/decreased depending on specific landowner goals. They can be extended to enhance non-timber resources (e.g., aesthetics, wildlife food and shelter, and old growth characteristics) if the landowner is willing to accept reduced growth rates and forgo some timber revenues. In the case of low risk, vigorous, high quality trees, the extended rotations can increase the supply of sawtimber and veneer, therefore, the total value. Just as trees can be held longer, they can also be harvested earlier to respond to variable market conditions (supply and demand economics), manage the flow of certain timber products or income, or divide/combine stands to meet other goals.

Reaching the optimum maximum diameter class is not the only criterion for tree selection. Other marking criteria (risk, vigor, spacing, quality, and basal area stocking levels) take precedence, and may result in a specific tree being retained longer. Vigorous, low risk, high quality trees may be retained well beyond the target diameter, for example, if stocking in the maximum diameter class is too low or other poorer quality trees are removed instead.

Flexibility exists in the selection of an optimum maximum diameter class. The diameter class chosen, however, is a key factor in the determination of the optimum number of trees needed in each of the other various diameter classes – from the smallest to the largest – to ensure that quality trees are available to replace those harvested.

PASSIVE OR NON-MANAGEMENT OPTIONS

Figure 2-30: Passive management is the most appropriate approach with fragile plant communities such as this relic white pine stand on cliffs in a stream-side riparian zone.

Some landowners and resource managers choose to "let nature take its course" on some forestland. In such cases, they make a conscious management decision to not actively manipulate the vegetation. This passive management is not considered a silvicultural system since it does not involve manipulation of vegetation.

Landowners and managers have different reasons for choosing to not actively manipulate vegetation. They may wish to protect and preserve fragile or special sites or communities (e.g., cliff communities, springs, groves of large old trees, and cultural sites). They may wish to develop habitat for specific wildlife that prefers relatively undisturbed forests. They may enjoy the appearance (aesthetics) and the recreational opportunities. Philosophical reasons may include the desire to allow nature to develop free of human impacts. Wilderness areas and some research control sites may be passively managed.

The concepts of "preservation" and "natural dynamics free of human impacts" are relative. Forests are dynamic communities that are continuously changing and adapting to external inputs and internal disturbances. Natural processes like forest succession, plant competition, wildlife and insect activity, tree aging and decay, windstorms, fires, and climate change will cause changes in forest composition, structure, and function over time. Forests cannot be maintained in a static, unchanging condition. Also, there are no forest ecosystems undisturbed by human activities. Disturbance has occurred through impacts on climate, atmospheric composition and inputs, fire control, management of wildlife populations (intentional and unintentional), introduction of exotics, recreational use, other human uses, etc. Passively managed forests will continue to change and will be subjected to human impacts, however, these changes and impacts often will be different than in actively managed forests.

Passive management does require monitoring, and certain events may necessitate the implementation of some short-term active practices. Examples include control of exotics, fire management, disease and insect management, wildlife management, recreation management, removal of diseased or weakened trees that pose safety hazards, and loss of attributes desired by the landowner. Passive management requires an understanding of the effects of natural processes and the impacts of other human activities (internal and external to the forest) on the development of the forest. This knowledge will facilitate the achievement of landowner objectives, and minimize the chances of counterproductive results or unintended consequences. In some situations, a blend of passive management and active silvicultural treatment may most effectively achieve landowner goals.

SILVICULTURAL SYSTEMS SUMMARY

As discussed in previous sections of this chapter, each of the silvicultural systems and regeneration harvest methods have a number of variations that can be employed to tailor them to the specific species and sites involved. The choices can be confusing, but hopefully this summary will help sort things out.

EVEN-AGED SILVICULTURAL SYSTEMS (NORMALLY USED FOR SUN-LOVING SPECIES)

Clearcut
A complete overstory removal designed to facilitate regeneration by natural seeding, direct seeding or planting.

Coppice
A complete overstory removal (clearcut) designed to promote regeneration through sprouts and suckers.

Overstory Removal
A complete removal of the overstory in a single harvest, applied to any even-aged cover type if adequate regeneration is already established (used to accelerate release of a new stand).

Seed-tree
All overstory trees, except for about three to 10 seed trees per acre are removed to facilitate regeneration by natural seeding.

Shelterwood
A complete overstory removal in two to three harvests spaced over a period of years. The residual trees from the first cut serve to modify understory conditions to create a more favorable environment for reproduction and provide a seed source. They are removed when the regeneration is established.

UNEVEN-AGED SILVICULTURAL SYSTEMS (NORMALLY USED FOR SHADE-TOLERANT SPECIES)

Single-tree Selection
Individual trees are harvested from all size classes on a recurring cycle. Regeneration occurs naturally in the openings created (favors species that are more shade-tolerant).

Group Selection
Trees are removed in small groups on a recurring cycle. Regeneration occurs naturally in the openings created (favors species that require more light for regeneration).

SIGNIFICANCE OF TABLE 2-1 TO THE WISCONSIN COOPERATING FORESTER PROGRAM

Table 2-1 (page 41) summarizes the regeneration harvest systems that are generally recognized as acceptable and widely applied in Wisconsin. The designations are substantiated in forestry research literature and further elaborated in the Wisconsin DNR *Silviculture and Forest Aesthetics Handbook, 2431.5*. Under the framework established by NR 1.213(3) b, Wisconsin Administrative Code, all forest management and timber harvesting assistance provided by the DNR and Cooperating Foresters must be consistent with the sideboards established in Table 2-1. Exceptions will be granted only if a science-based management commitment describing an alternative method is submitted to and approved by the Department of Natural Resources in advance. Procedures regarding management commitments can be found in Chapter 21 of the Wisconsin DNR *Private Forestry Handbook, 24705.21*.

GENERALLY ACCEPTED REGENERATION HARVEST METHODS BY FOREST COVER TYPE

	Natural Regeneration Harvest Method						**Artificial Regeneration Method**[5]
	Even-aged Systems[6]				**Uneven-aged Systems**		**Planting/Direct Seeding**
Forest Cover Types[1]	Coppice	Clearcut	Seed-tree	Shelterwood	Single-tree Selection	Group Selection	
Jack pine		X	X				X
Red pine							X
White pine			X	X			X
Aspen	X						
White birch		X[2]		X			
Scrub oak	X	X		X			
Oak		X		X			X
Black walnut							X
Red maple	X			X		X	
Central hardwoods				X		X	
Northern hardwoods				X	X	X	
Hemlock hardwoods[4]				X	X		
Fir-spruce		X[2]		X			X
Swamp conifer-fir		X[2]		X			
Black spruce		X[2]		X			
Tamarack		X[2]					
Cedar[4]		X[2]		X			
Swamp hardwoods				X			
Bottomland hardwoods	X[3]			X		X	

1 Harvest methods apply to the **cover type to be regenerated**, not necessarily the currently existing cover type.

2 Strip clearcutting generally recommended.

3 When silver maple predominates.

4 Regeneration may be hampered due to animal browsing (herbivory).

5 Refers to reforestation, not afforestation.

6 Overstory removal is acceptable for any timber type managed on an even-aged basis if desirable regeneration is well-established.

Table 2-1: Generally Accepted Regeneration Harvest Methods by Forest Cover Type

SALVAGE HARVESTS

Figure 2-31: Forest management plans are often modified by natural disturbances like this major wind storm in a northern Wisconsin hemlock stand.

In addition to regeneration harvests employed as part of a silvicultural system, salvage harvests are carried out as part of an overall forest management program. Unlike regeneration harvests, which are also designed to facilitate regeneration of the new stand, salvage harvests are geared only to the recovery and use of dead or dying trees that would otherwise go unharvested. Wind events, fire, flooding, insect and disease activity, and weather extremes can all wreak havoc on the best of forest management plans. High quality trees can have significant economic value and often justify a salvage effort. Removal of infected trees is often necessary to prevent additional mortality.

It should also be remembered, however, that dead and dying trees are part of the overall forest system, and provide a number of benefits to wildlife and other ecological processes. Decisions to conduct or not conduct a particular salvage operation are often a balance between potential economic return, impact on stand silviculture, risk of wildfire, cost of salvage, and the ecological value of leaving the trees in place. When mortality is significant, a regeneration strategy should be developed to facilitate regeneration, based on current conditions and landowner goals.

UNSUSTAINABLE CUTTING METHODS

A silvicultural system is a planned program of treatments over the life of a stand. Other cutting methods exist primarily to maximize short-term economic gain, and are not part of a long-term plan to ensure regeneration of a healthy, vigorous stand on a sustainable basis.

The following examples of unsustainable cutting methods are not an all-inclusive list. These methods may result in a new stand of trees, but due to the lack of consideration of specific species requirements, they often lead to stand degradation and are not considered generally accepted silvicultural practices that result in sustainable forestry:

- **Diameter limit cutting** is cutting all trees above a set diameter regardless of the impact on stand structure, stand quality, tree quality, species composition, or regeneration needs. At times referred to as a "selective cut," the only consideration is diameter as opposed to specific criteria employed in a true single-tree selection harvest under the uneven-aged silvicultural system.
- **Economic clearcutting**, where any tree of economic value is cut with no consideration for site, silvics of the species involved or regeneration needs. This practice differs from a clearcut in the even-aged silvicultural system where all trees are harvested, regardless of value, in order to ensure residual shade and competition does not hamper the regeneration and development of a new stand.
- **High grading** (Figures 2-32 and 2-33), also referred to as "selective logging," is the practice of cutting only the largest, most valuable trees in a stand and leaving low value and poor quality trees to dominate. This practice is NOT the same as a single-tree selection regeneration harvest described in the silvicultural systems section (see page 36). High grading is not designed to enhance the quality and reproductive potential of the residual stand, but maximize immediate revenue. The term "selective logging" is sometimes used intentionally by unscrupulous loggers to create false expectations on the part of landowners.

It is emphasized that economic gain and sustainability ARE compatible. Using creativity and imagination in the application of sound silviculture will best achieve both goals in the long-run.

Figure 2-32: Before

Figure 2-33: After

Figures 2-32 and 2-33: The figures above depict the results of a typical "high grade." All the larger trees with the greatest economic value have been removed leaving only poor quality trees behind. No consideration was given to size and age distribution, residual stocking levels or regeneration needs.

MANAGEMENT PRESCRIPTIONS

As the previous sections of this chapter describe, the basic question of "what to grow and how to grow it" is not as simple as it may first appear. Indeed, the answer can involve the collection and evaluation of a great deal of information, and the consideration of a number of alternative strategies. **In the end, the question – "what to grow and how to grow it" – must be answered clearly, logically and completely.** This final step in the decision-making process can be compared to the last phase of designing a new home – the development of a blueprint which spells out in detail exactly how your vision transfers to clear, specific action. The silvicultural counterpart to that blueprint is a management prescription.

A **management prescription** or recommendation is a detailed description of a specific treatment or cutting scheme designed to implement a specific stand management objective. Prescriptions describe the individual activities necessary to implement the overall silvicultural system in a given stand.

A **forest management plan** is written for entire properties and identifies general landowner goals as well as other property and landscape information. The more detailed plans also identify specific stand management objectives, and the series of management prescriptions describing specific actions needed for all stands for an entire operational period (see Chapter 9: Forest Management Planning).

It is important a management prescription reflect all relevant factors and be written in a clear, logical fashion. Less complex prescriptions are normally written in a narrative format. More complex prescriptions involving a number of interdependent activities with the outcomes of each leading to different pathways may include a decision tree or diagram (see Figure 2-34).

The development of a detailed management prescription for a given stand is a complex process. It requires a thorough understanding of the landowner's objectives, silviculture, silvics, capabilities and limitations of the resource, and collection and evaluation of considerable vegetative and site data. Since each stand is unique, a forester and possibly other resource professionals should be involved to provide technical assistance.

MANAGEMENT PRESCRIPTIONS: FACTORS TO CONSIDER

1. **Landowner's Objective**
   - Is it sustainable?
   - Were all opportunities considered?

2. **Assess Biological Characteristics**
   - Site capabilities
   - Past disturbances
   - Current vegetative condition and potentials (growth and succession)
   - Forest health and protection

3. **Consider Other Relevant Environmental, Cultural, Social, and Economic Factors Such As:**
   - Aesthetics
   - Recreation
   - Wildlife
   - Presence of endangered species
   - Invasive species
   - Landscape scale issues (critical habitat, percentage of land in a cover type, etc.)
   - Regulations (statutes, rules or local ordinances)
   - Traditions (possibly related to ethnic heritage)
   - Markets
   - Community viability
   - Watershed protection and erosion control

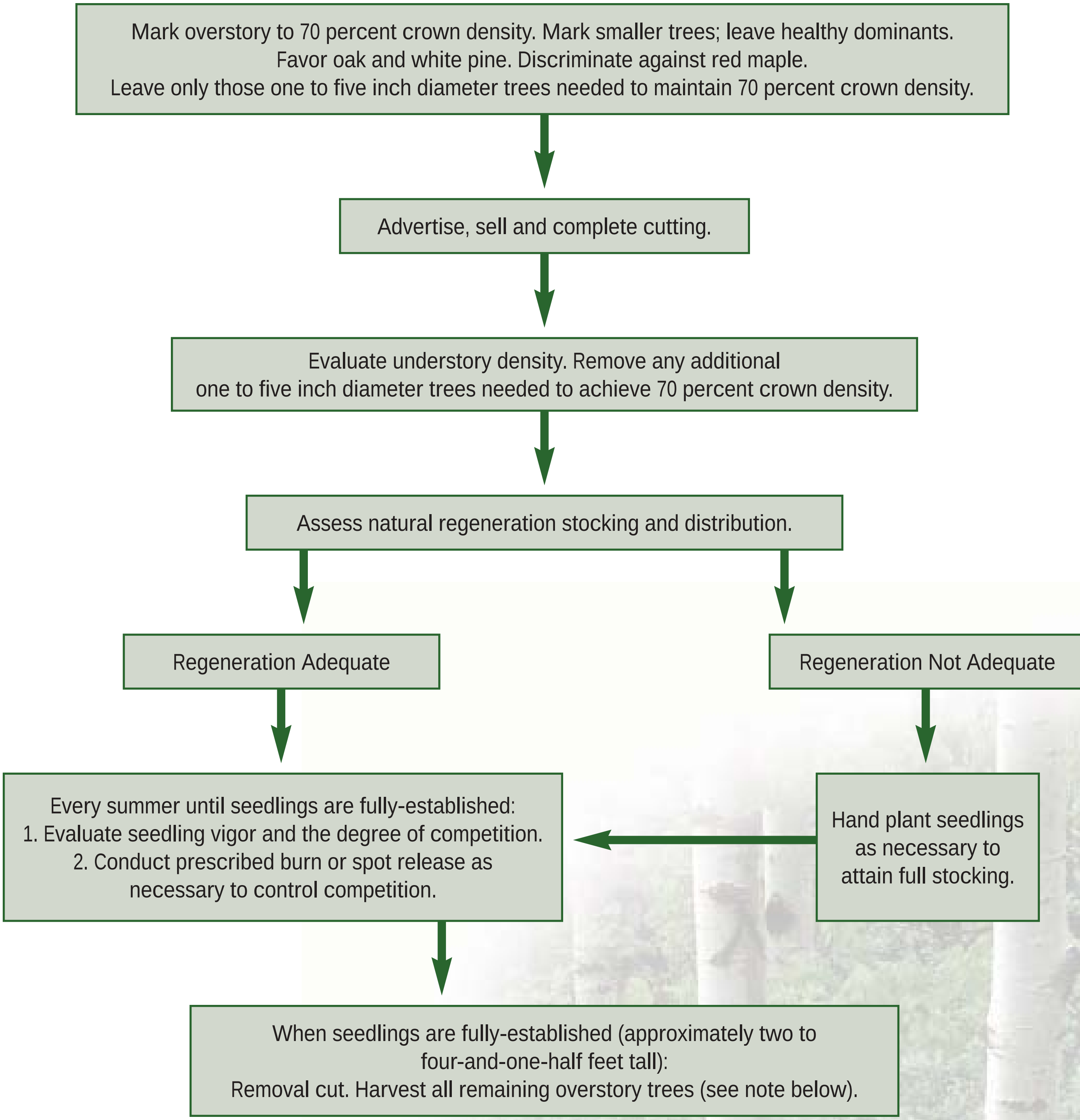

Figure 2-34: An example of a management prescription designed to implement a shelterwood regeneration harvest in a mature red oak stand. (Note: While this particular management prescription has a timber management focus, it could easily be modified to incorporate other objectives. To enhance wildlife habitat, for example, a portion of the residual overstory (20 to 30 percent) could be retained during the final removal cut to provide for a continuous supply of mast. The shade from the scattered residual large canopy red oak would somewhat hamper seedling growth and distribution, but the stand would still regenerate and the red oak cover type would be perpetuated long-term.) There is a significant amount of flexibility available to tailor a silvicultural system to meet various needs as long as the primary objective to regenerate the stand is not compromised.

RESOURCES FOR ADDITIONAL INFORMATION

APPROACHES TO ECOLOGICALLY BASED FOREST MANAGEMENT ON PRIVATE LANDS

Kotar, J. (1997). *Approaches to ecologically based forest management on private lands*. University of Minnesota Extension Service, Publication NR-604.

THE DICTIONARY OF FORESTRY

Helms, J. A. (Ed.). (1998). *The dictionary of forestry*. Society of American Foresters.

THE PRACTICE OF SILVICULTURE (7TH ED.)

Smith, D. M. (1962). *The practice of silviculture (7th ed.)*. New York: Wiley.

SILVICULTURE: CONCEPTS AND APPLICATIONS

Nyland, R. D. (1996). *Silviculture: Concepts and applications*. New York: McGraw-Hill.

SILVICULTURE AND FOREST AESTHETICS HANDBOOK, PUBL. NO. 2431.5

Wisconsin Department of Natural Resources. (2002). *Silviculture and forest aesthetics handbook*. Madison: Wisconsin Department of Natural Resources.

These resources are specific to the information in this chapter only. Refer to the Resource Directory for additional resources related to this chapter.

NOTE: Figures 2-9, 2-10, 2-11, 2-13, 2-14, 2-16, 2-17, 2-18, 2-19, 2-27, 2-28, 2-32 and 2-33 use computer-generated simulations to depict various harvest methods listed in Table 2-1 (see page 41). The images were produced by Andrew M. Stoltman as part of the *Forest Visualization at Multiple Scales for Management* project at the University of Wisconsin-Madison, Department of Forest Ecology and Management.